Sea Ice Modeling for Climate Applications

Or "A perspective on how to target model improvements"

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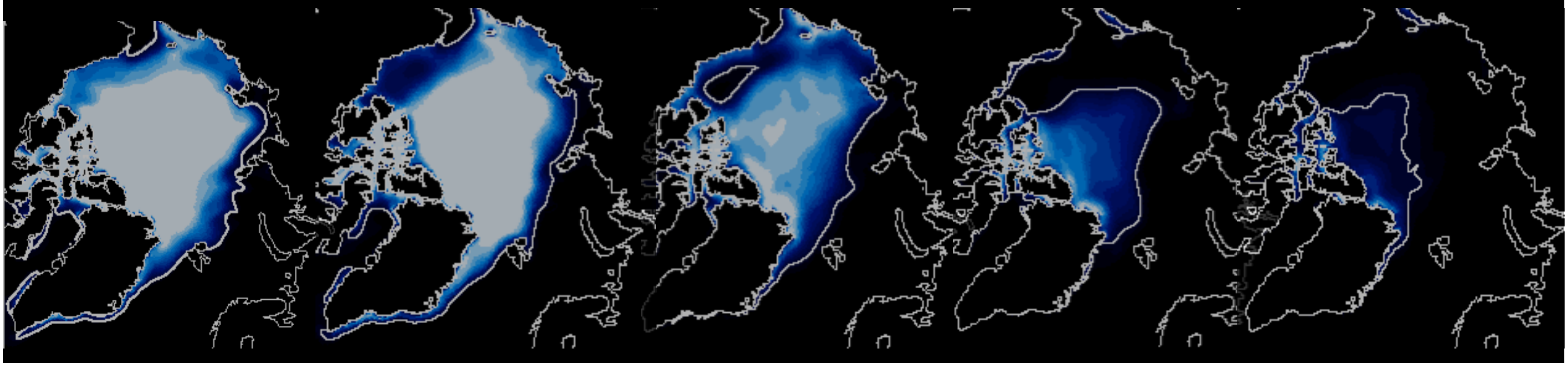
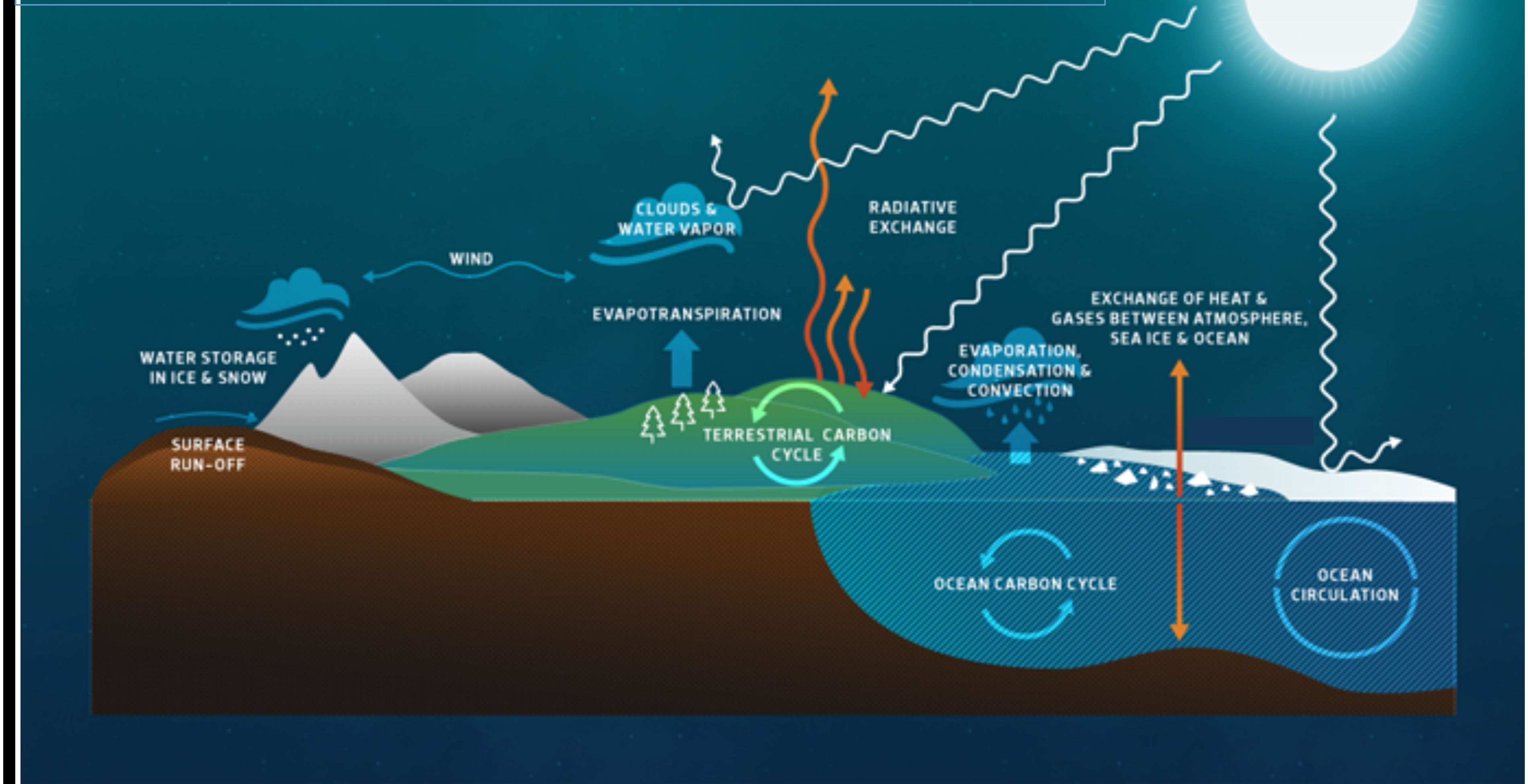


Different flavors of models used for climate studies

- Stand-alone sea ice models
  - Prescribed atmosphere and ocean forcing; no atm/ocean feedbacks
- Ice-ocean coupled models
  - Prescribed atmospheric forcing but an interactive ocean model; no feedbacks to atmosphere
- Fully coupled models
  - atmosphere/ocean/ice/land models
  - not tightly constrained to observational record; feedbacks active
- Earth system models
  - coupled models with active carbon cycle components

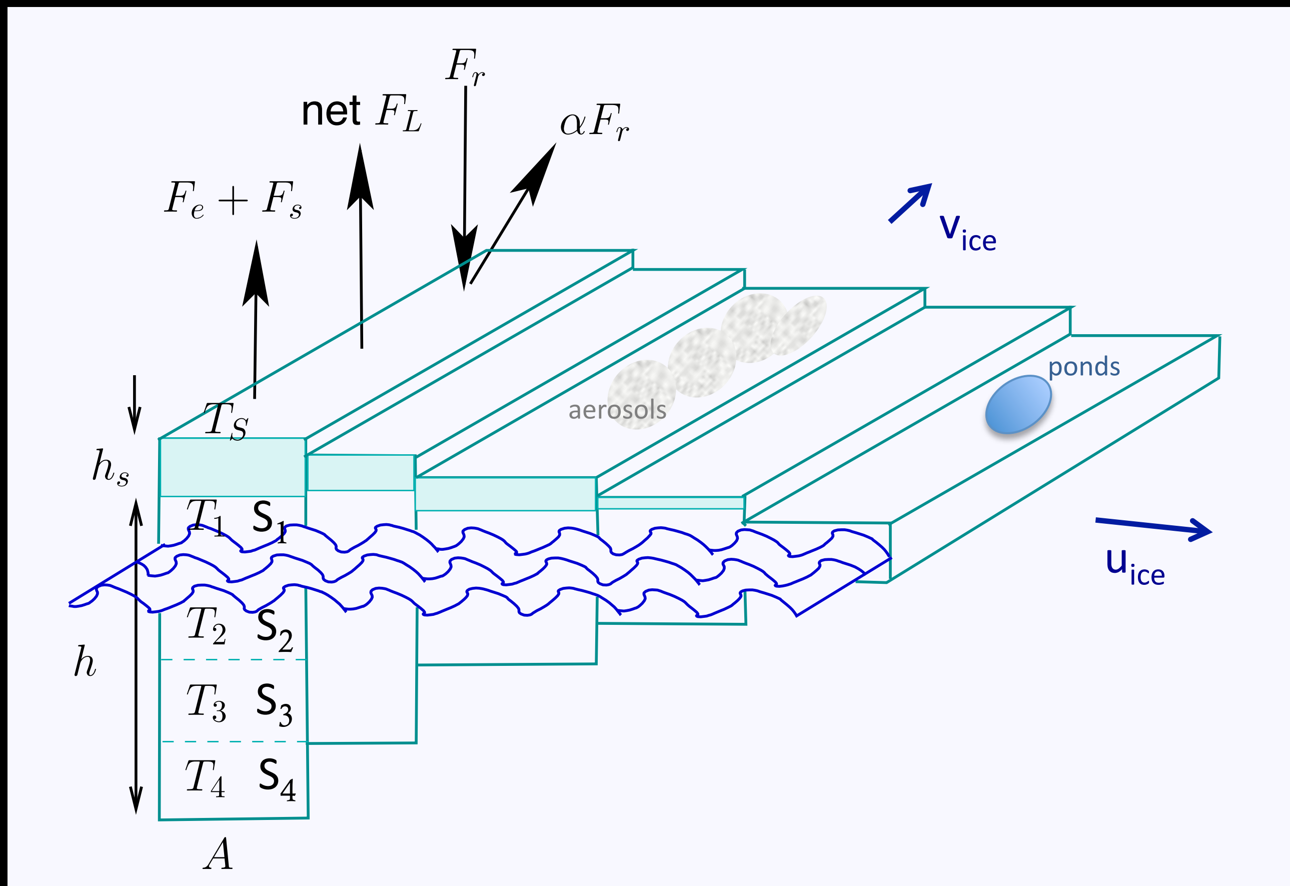
Include: atmosphere, ocean, land, sea ice
More recently ice sheets, carbon cycle included
Components coupled through exchange of heat, water, carbon



History of sea ice components within climate models

- Initial models (~1970s) had **no sea ice** component but raised albedo for cold (<-2C) wet surface areas
- In ~1980s **thermodynamic** sea ice components were included
- Coupled systems incorporated **dynamic** sea ice components (~1990s) of varying complexity
- **Subgridscale Ice thickness distributions** were introduced into some coupled models (~2000s)
- More physically based **shortwave treatment** and associated capabilities (ponds, black carbon) in 2000s
- Sea ice hydrology (prognostic salinity), biogeochemistry, improved ponds, snow improvements, others - NOW

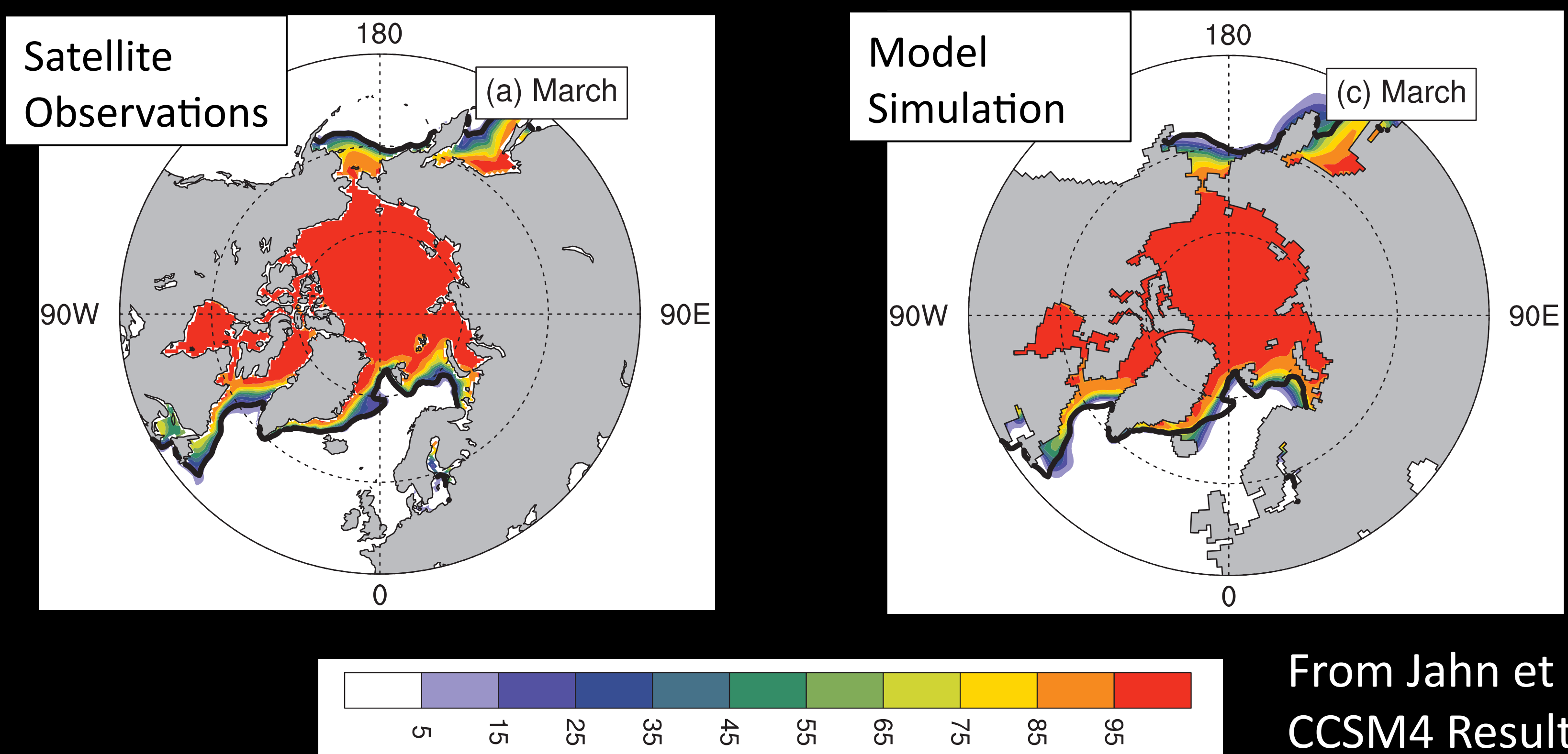
Where are we today?



Schematic courtesy of Cecilia Bitz

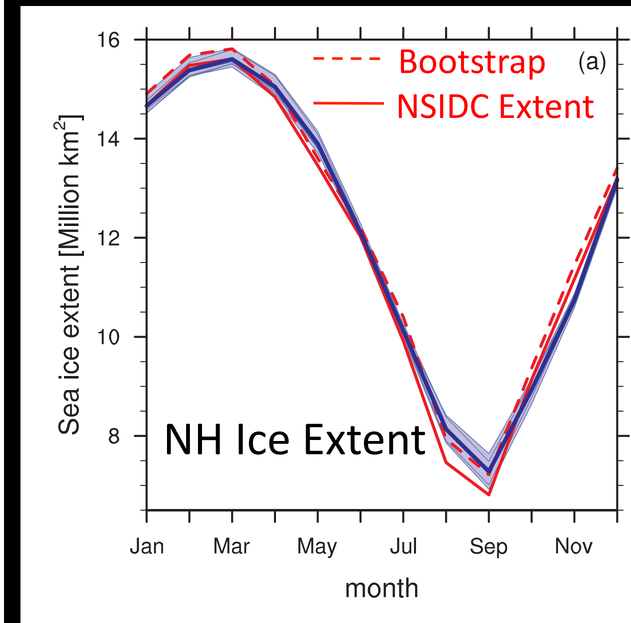
What do we need for climate applications?

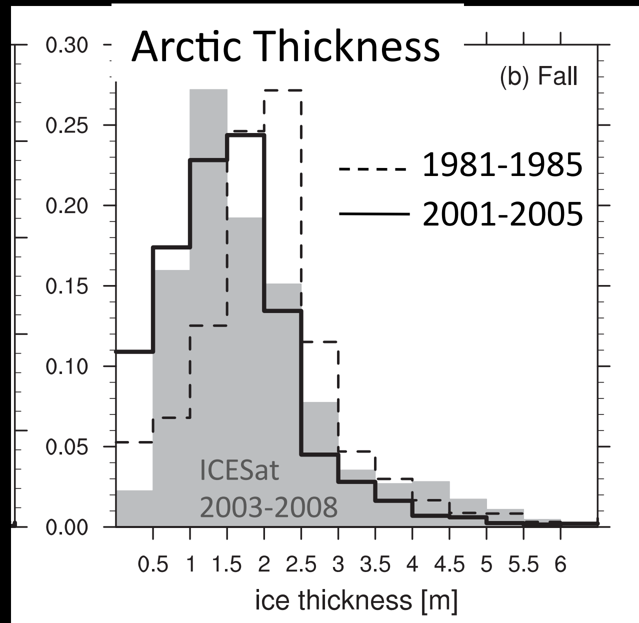
- Model which simulates a reasonable mean state and variability of sea ice – at large scale
  - Concentration, thickness, motion, mass budgets

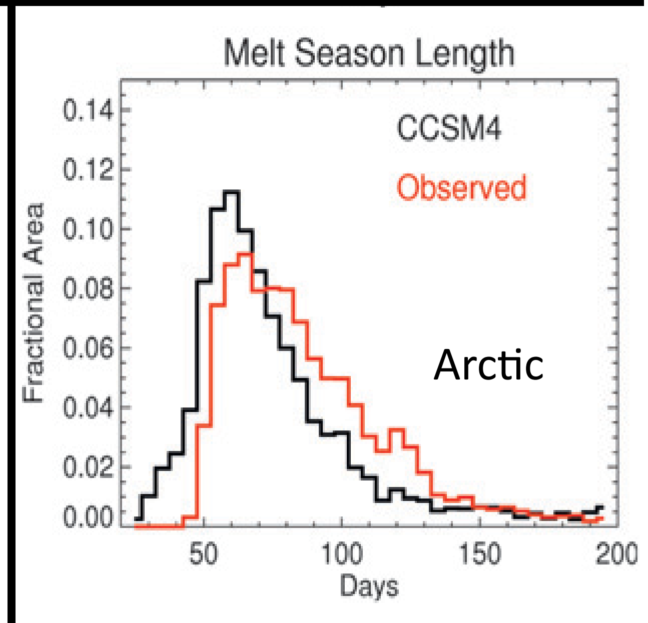


From Jahn et al., 2012
CCSM4 Results

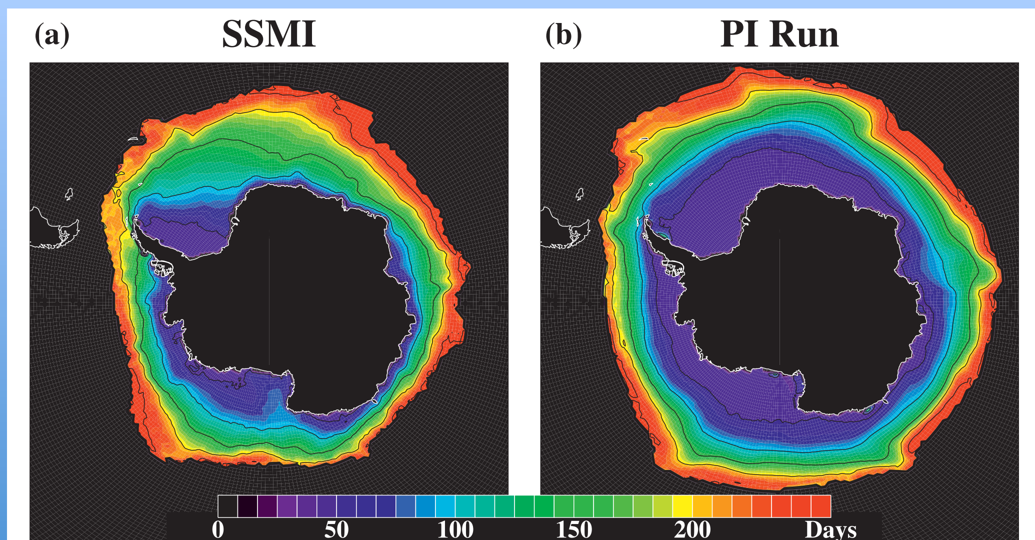
What do we need for climate applications?







Jahn et al 2012



Day of Ice Advance
Landrum et al., 2012

What do we need for climate applications?

- Model which simulates a reasonable mean state and variability of sea ice – at large scale
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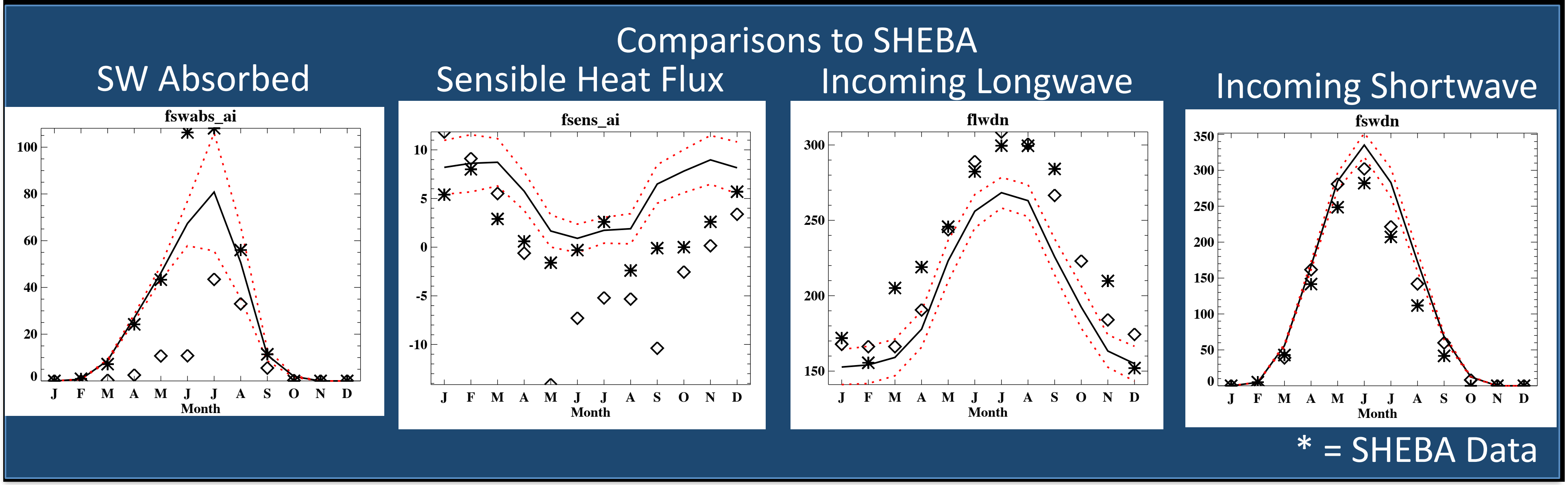
- Realistically simulates ice-ocean-atmosphere exchanges of heat and moisture



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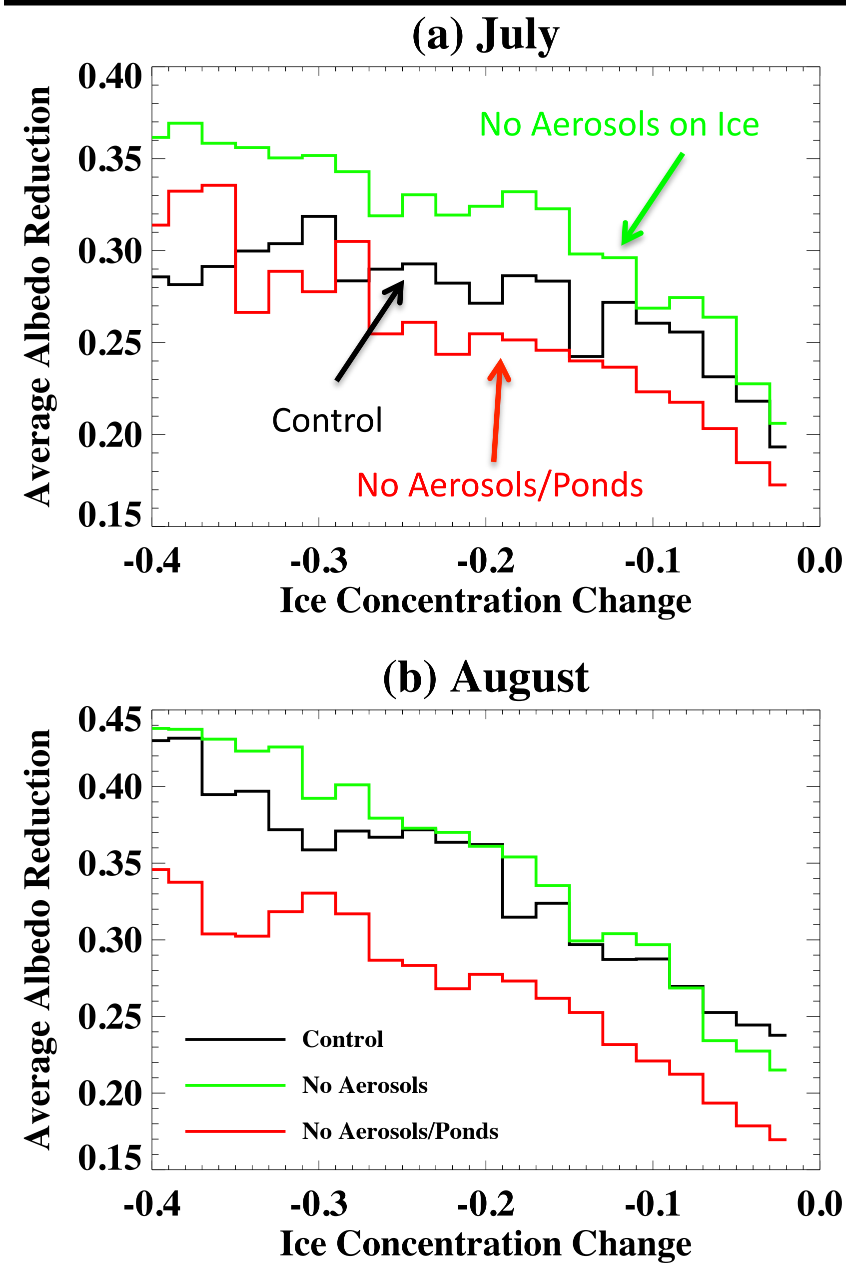
- Model which simulates a reasonable mean state and variability of sea ice – at large scale
  - Concentration, thickness, motion, mass budgets
- Realistically simulates ice-ocean-atmosphere exchanges of heat and moisture
- Realistically simulates response to climate perturbations - key climate feedbacks

Can be difficult to assess a priori – often assume that if we include more realism/ better physics and this influences feedbacks then we should incorporate this realism



Example: Melt Ponds/Aerosols

Surface Albedo Response
$2XCO_2$-$1XCO_2$

For regions of same ice area change -

July/August albedo change **larger when ponds included**

- Increased ponding in warm climate
- Stronger albedo feedback

July albedo change **smaller when aerosols included**

- Increased meltwater flushing of aerosols in warmer climate
- Weaker albedo feedback

Holland et al., 2012

Model Development Constraints - For Climate Applications

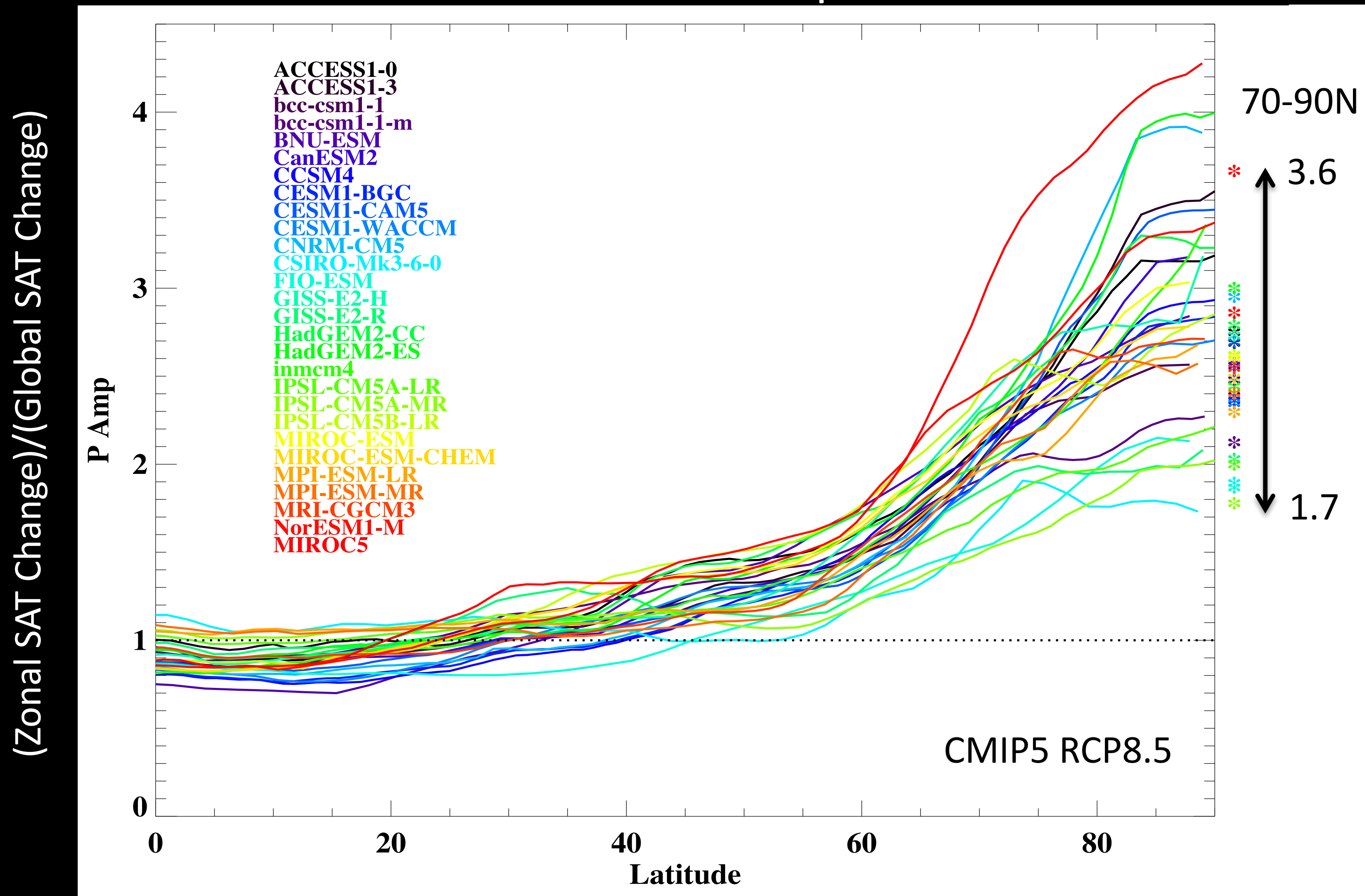
- Developments must be heat and water conserving
- Developments must work for all climate regimes
  - Arctic/Antarctic; Present day climate, future climate, climates of the past (Last Glacial Maximum, Etc.)
  - Model developments are ideally process based
  - Should consider processes that may have little impact in present climate but influence the climate response
- Developments should consider computational costs
  - Simulations are runs for 1000s of years, numerous ensemble members
- Developments should target processes of importance from a climate perspective

Why target snow on sea ice?

- Many aspects are currently quite simple in many models
- Evidence that the snow simulation matters for feedbacks
- Feeling that there are numerous areas where considerable progress is possible

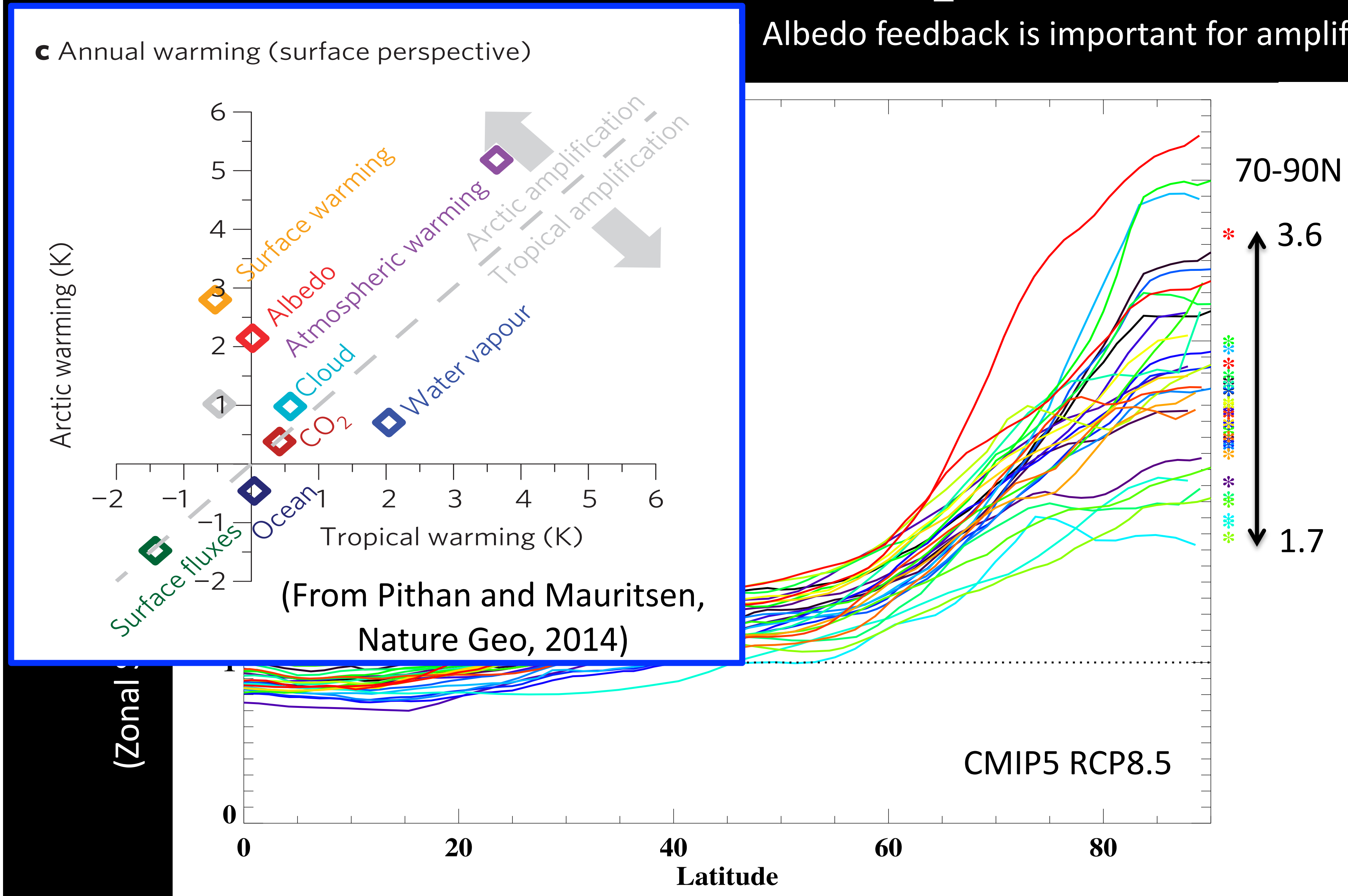
Simulated Arctic Amplification

Across model scatter in Arctic Amplification is considerable

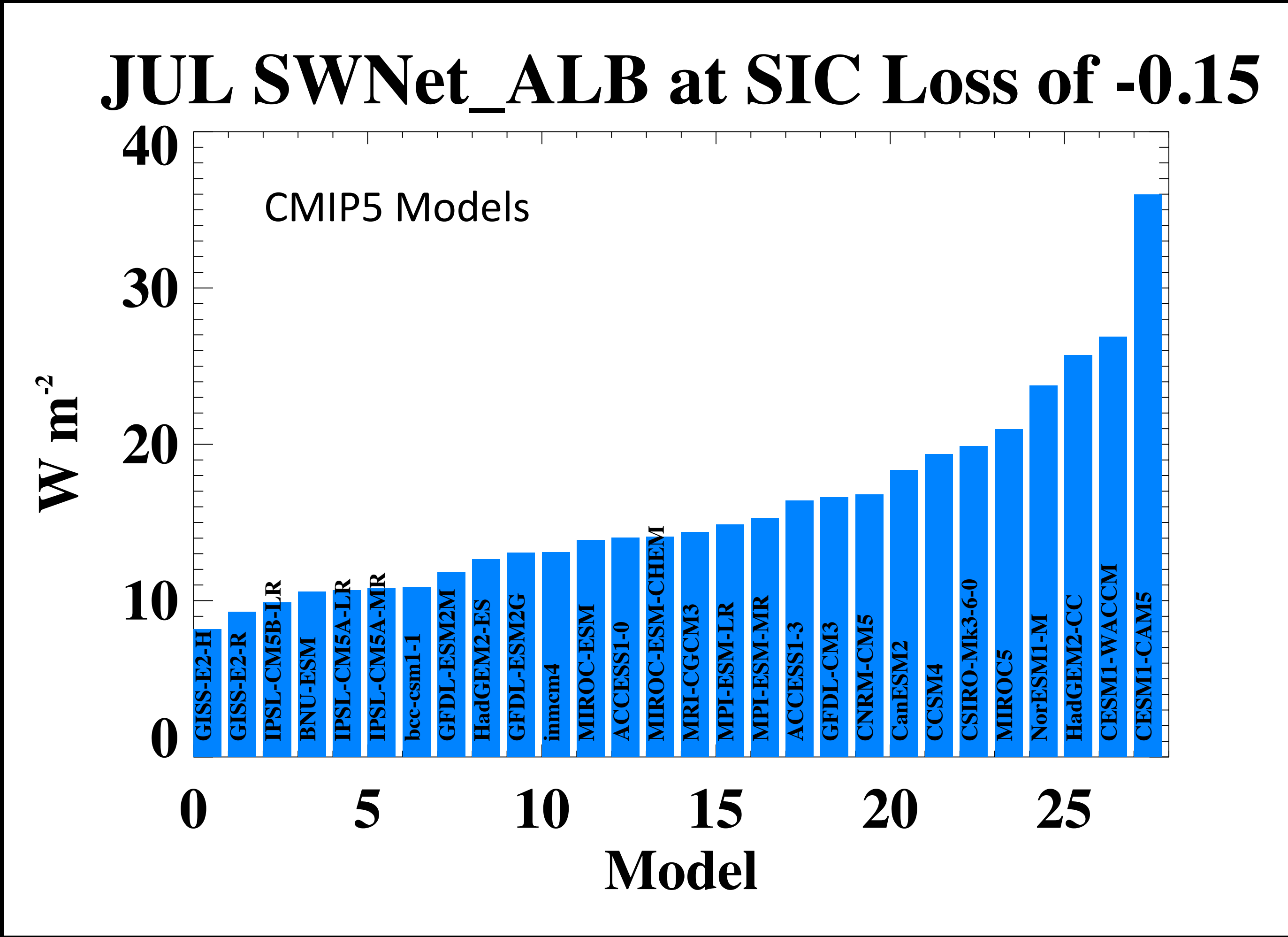


Simulated Arctic Amplification

Albedo feedback is important for amplification

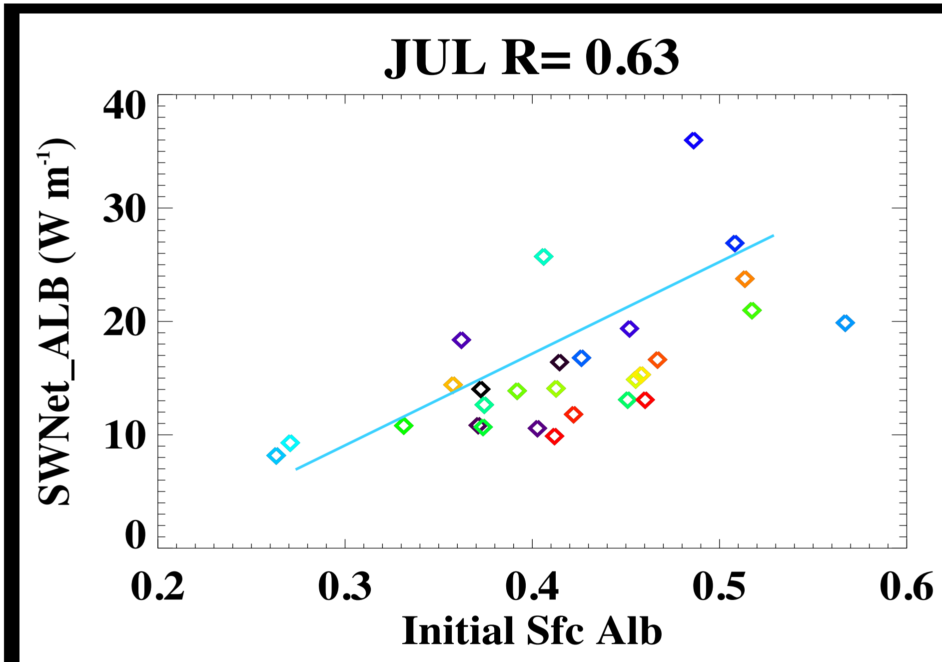


What is important for across-model scatter?



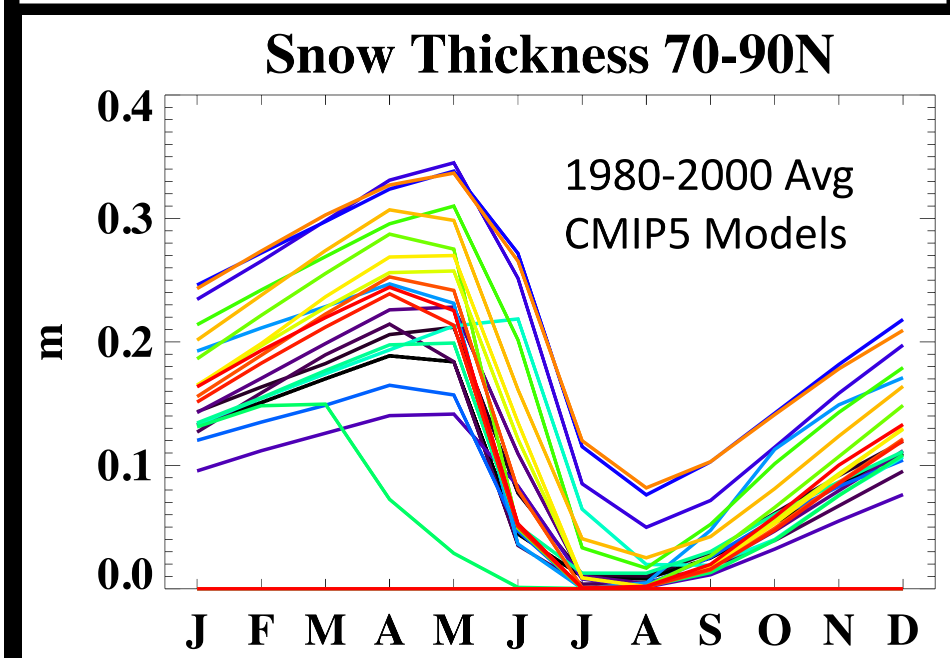
For the same ice loss, the increase in albedo-related net solar heating can vary by a factor of >3 across models

Holland and Landrum, in press



For the same ice area loss –

Larger increases in net solar heating occur in models with higher initial (late 20th century) surface albedo



Late 20th century surface albedo influenced by:

- Simulated surface state
  - snow cover conditions
  - ponding on sea ice
- Possible tuning of albedo values

Holland and Landrum, in press

- Given the need to improve feedbacks within climate models, what snow related processes should be targeted?
- How can we better go about improving these processes within models?
- What processes may be important for other applications – seasonal forecasting, etc.
- What processes may be important for different climate regimes?

Questions?